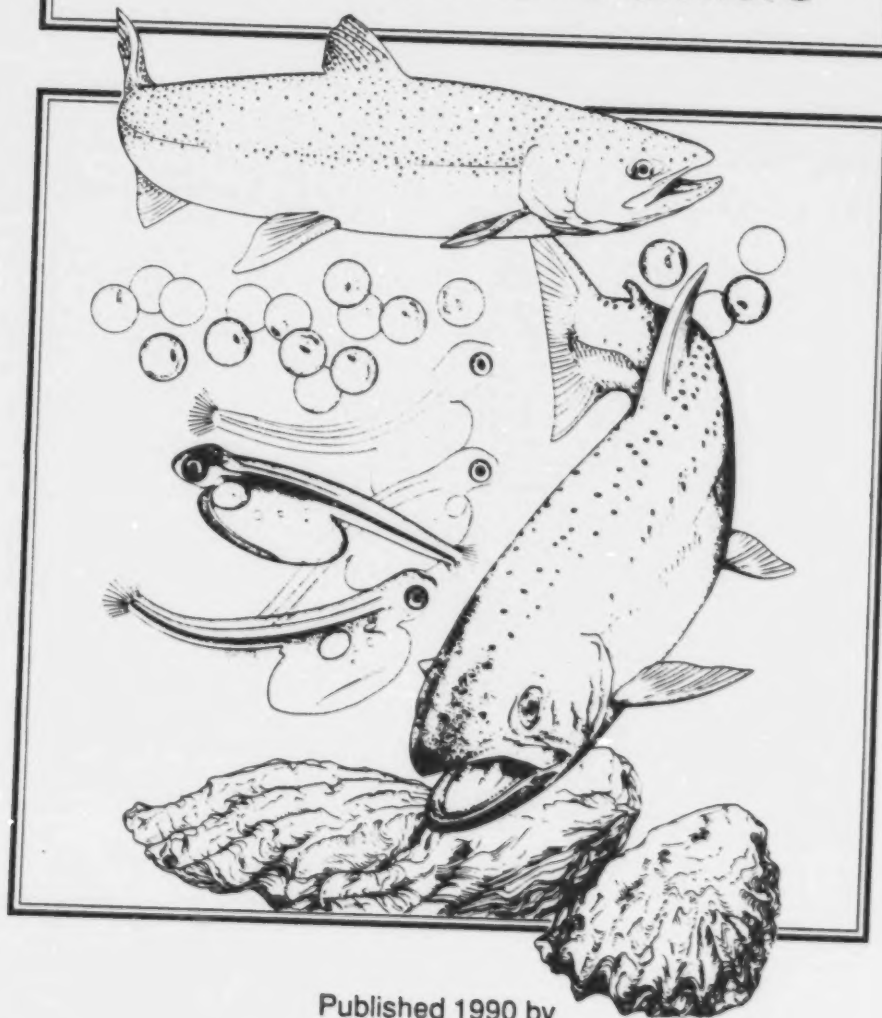


Aquaculture Industry Development Report
**Ensiling Salmon Mortalities:
Suggested Guidelines
For B.C. Salmon Farmers**



Published 1990 by



Province of British Columbia
Ministry of Agriculture and Fisheries
Aquaculture and Commercial Fisheries Branch
Hon. John Savage, Minister

No. 90-3

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Suggested Guidelines
For B.C. Salmon Farmers**

October, 1990

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NOTICE TO READERS

For the convenience of salmon farmers, brand or trade names and specific suppliers are used throughout this publication. This does not constitute an endorsement of the product nor a suggestion that like products are not effective. The equipment and materials suppliers identified in Appendix A do not comprise an exhaustive listing and readers are encouraged to investigate additional suppliers in their local regions.

This publication is the result of extensive literary research, field trials and industry interviews. The ministry acknowledges that further technological developments and procedural refinements will occur as more aquaculture companies incorporate salmon mortality ensiling into their plan of operations. Therefore, these guidelines will be reviewed and revised for republication in September, 1991.

Copies of this publication may be obtained from:

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ACKNOWLEDGEMENTS

This report would not have been possible without the cooperation and assistance of personnel from many organizations, including: Barkley Sea Farms Ltd., British Columbia Packers Ltd., Ibec Aquaculture Corporation, Kanish Aquafarms Ltd., North Island Mariculture Association, Pacific National Group Ltd., Sea Farm Canada Inc., the University of British Columbia Research Farm, and Whaletown Seafood Equipment. The authors are grateful for all the advice, insights and equipment these individuals were able to provide.

INTRODUCTION

If you ask most salmon farmers along this coast what the most unpleasant task around the farm is, the answer probably will be disposing of fish mortalities, or "morts", as they are referred to in the industry. Overflowing mort pits, the odour of decay hanging over the bay when the wind shifts, fellow ferry passengers complaining about the stench from those "sealed" totes in the back of that pickup truck parked beside them... Such problems attest to the logistical headache and public embarrassment the issue of mort disposal has become for too many fish farmers.

On a salmon farm where the ensiling process is used, one will still find morts. However, there is a significant difference. Except for the few hours of the day when they are being removed from the pens and processed, you never see or smell the morts again. This not only keeps neighbors and Waste Management inspectors happy, but also greatly simplifies the on-site handling, storage and eventual transportation of this waste by-product.

To help make the technology of fish ensiling available to all British Columbia fish farmers, extensive research and field trials have resulted in this publication. It is hoped that the information and procedures outlined herein will assist the industry in establishing safe, efficient and cost effective mort silage operations. In doing so, salmon farmers will have transformed waste into an opportunity rather than a liability - an achievement which many progressive industries have managed.

The Aquaculture Industry Development Section has a responsibility to assist industry in the identification and development of practical farm management programs and systems. This publication is one part of the ministry's overall program to facilitate effective resource utilization by both fish producers and processors.

THE ENSILING PROCESS

Salmon mortalities, or "morts", are incurred as part of normal fish farming production. Mortality rates vary with the species being reared, fish stress levels and health, husbandry methods employed and plankton problems. Normally, a seasonal increase in mortality rate is experienced as water temperatures increase. Projections indicate that British Columbia's salmon farming industry is expected to produce 20,000 tonnes of product in 1991. At this production level, the industry will also generate an estimated 3,500 to 6,000 tonnes of morts.

Storage and disposal of these mortalities has become a pressing concern as traditional methods of disposal, such as mort pits and landfills, are no longer options in many locations. The process of ensiling is a viable and practical solution for effective handling and storage of salmon mortalities. Acid ensiling produces a stable liquid with an inoffensive odour that can be stored for long periods thereby eliminating the urgency for frequent disposal.

PRIMARY ADVANTAGES OF SILAGE AS A DISPOSAL METHOD:

- a) greatly reduces odours and handling problems traditionally associated with putrefied morts;
- b) will reduce the volume of mortalities by approximately 15%;
- c) a cost effective method for practical long-term waste storage;
- d) affords farmers more flexibility in determining transportation methods and frequency for removing silage from the farm;
- e) gives the farmer a wider range of utilization and disposal options for a mort by-product;
- f) does not require a waste management permit.

Fish ensiling is a relatively simple process that has been known and successfully used since the 1920's. Basically, fish are ground into a slurry and the pH is reduced by adding acid. The lowered pH enhances the activity of the naturally present proteolytic enzymes in dead fish or offal. Proteolytic enzymes are concentrated in the gut region of a fish and are

responsible for self-digestion (autolysis) and consequent liquefaction. The optimum pH range for autolysis is between 2 to 4.5. The lowered pH inhibits bacterial degradation thereby controlling putrefaction and odours associated with decomposition. If insufficient acid is used in the process, the silage will spoil (Tatterson, 1982). The process can be accelerated by increasing temperature and by frequent mixing.

At present, the University of British Columbia Research Farm at Oyster River is accepting ensiled salmon morts which are added to the site's cow manure storage facility. In the spring of 1991 trials will be conducted with this mixture by applying it as an irrigated fertilizer to the farm's agricultural fields. The Research Farm's criteria for accepting silage is that there are no particles larger than 1.27 cm (1/2") in diameter. On the Sunshine Coast, a fish compost operation (Cousins Aquapost) will also accept mort silage, and a liquid fertilizer facility utilizing fish silage is in the planning stages for the Tofino area.

Salmon silage is a versatile product which can be converted to fish fertilizer, used in composting operations or, as practiced in Norway, utilized as a feed component for land farm animals. The adoption of ensiling technology by British Columbia's salmon farming industry is the first step in turning a difficult waste product into a potentially useful by-product.

ACID TYPES AND APPLICATION

Any acid can be used for fish ensiling. Organic acids, such as formic or propionic, have antiseptic properties which enable the silage to be stable at a relatively high pH of 4 to 4.5 (Tatterson and Windsor, 1974; Gildberg and Raa 1976, Tatterson, 1982, Raa, Gildberg and Strom 1983). Weak organic acids can penetrate fish cell walls more effectively than inorganic acids and accelerate the rate of autolysis (refer to Appendix D, Table 1). Organic acids are particularly useful for silage that is destined to be used as feed. Silage used for feed requires uniformly fresh raw material and must meet strict product specifications, which generally has precluded the use of salmon morts.

Organic acids are also less corrosive than mineral acids, and silage produced with organic acid does not normally require neutralization before use. The neutralization of silage is a laborious process with practical problems and should not be attempted by salmon farmers due to the large volume of gases produced during neutralization (Ministry of Agriculture and Fisheries/University of British Columbia field trials, 1990).

Though highly corrosive, inorganic acids are far less expensive than organic acids (Appendix A). Inorganic acids, such as sulphuric or hydrochloric acid, can be used exclusively, or can form the major portion in acid mixtures used to create silage destined for use as soil fertilizer. Silage produced solely with inorganic acids must have a pH of approximately 2 if bacterial spoilage is to be prevented (Edin, 1942). The low pH of this silage will require neutralization before use as a fertilizer, which will ultimately be incorporated into disposal cost.

Within three to seven days, at ambient temperatures of 23-30 °C, ground fish undergo liquefaction from the action of gut enzymes (Backoff 1976). The resulting silage is a very stable liquid (80% water) and has been successfully stored for 12 months (J. Richards, pers. comm.) If fresh morts are used, studies have found the only noticeable odour is a slight, bitter acid smell.

Based on results of joint Ministry of Agriculture and Fisheries/University of British Columbia (MAF/UBC) field trials and industry results, *preliminary* recommendations for silage acid recipes have been determined. For salmon silage, it is recommended that an amount of concentrated sulphuric (93.15%)¹ or formic (85%) acid equal to 3% of the total weight of morts (3% w/w, i.e. 3 kg of acid per 100 kg of morts) be added to the ground slurry. Pure sulphuric acid is adequate for the production of silage which is to be used for fertilizer. However, any addition of formic acid seems to accelerate the rate of liquefaction and may enhance antimicrobial characteristics. Hydrochloric acid could be used in place of sulphuric acid, but it is not as cost effective, and the presence of chlorine compounds in the silage may be viewed as undesirable for certain

¹ All acid concentrations cited in this publication are common commercial concentrations and should be used "as is".

utilization processes.

Acid mixtures of 6:1, 5:1, 3:1 and 1:1 sulphuric/formic are equally effective, but the cost of production increases significantly with an increase in formic acid.

**Costs of Sulphuric/Formic Acid Mixes
Per 1,000 Kg of Morts
(Bulk Prices - Van Waters & Rogers)**

Sulphuric:Formic Ratio	Cost
1:0	\$10.20
6:1	\$15.58
5:1	\$16.45
2:1	\$22.70
1:1	\$28.95
0:1	\$47.70

Many different formulation procedures for silage are possible (Appendix B). The recipes recommended here are based on specific field trials and methods currently used by a number of B.C. salmon farms. It is possible to reduce the amount of acid used, but this requires additional equipment and higher energy costs for more thorough and continuous mixing and heating to achieve rapid liquefaction. It is recommended that silage, especially that made with inorganic acids, be made in batches. This helps facilitate quality control (e.g., the monitoring of pH and the progress of liquefaction) prior to adding any given batch of silage to bulk storage containers. Experience has shown that production techniques used to create silage with formic acid can be less rigorous and batch processing may not be necessary (Sea Farm Canada, Soderman Cove, 1990).

In most large commercial silage facilities the acid is introduced during the grinding process with an acid metering pump. Individual salmon farms will produce relatively small volumes of silage and do not require this level of mechanization. The specific gravity of the acid in question can be used to determine appropriate volumes of acid for a given weight of morts.

Example A: Calculations For 3% w/w Sulphuric Acid Silage

Determine volume of 93.15% concentrated sulfuric acid (specific gravity of 1.836, i.e. 1 litre weighs 1.836 kilos) required to ensile 100 kilos of salmon mortalities:

At 3% w/w, 3 kilos of acid are needed to ensile 100 kg of morts (i.e. $100 \text{ kg} \times 3\% = 3 \text{ kg}$).

$$1.000 \text{ litre} / 1.836 \text{ kg} = ? \text{ litres} / 3 \text{ kg}$$

$$? = (1.000 \times 3) / 1.836$$

$$? = 1.633 \text{ litres of 93.15\% sulphuric acid}$$

Example B: Calculations For 5:1 Sulphuric/Formic Acid Silage

Determine volume of 93.15% concentrated sulphuric acid and 85% concentrated formic acid (specific gravity of 1.10) required to ensile 100 kilos of salmon mortalities.

At 3% w/w, 3 kilos of acid are needed to ensile 100 kg of morts. Therefore, at a 5:1 ratio, 2.5 kilos of sulphuric acid and 0.5 kilos of formic acid are required.

$$1.000 \text{ litre} / 1.836 \text{ kg} = ? \text{ litres} / 2.5 \text{ kg}$$

$$? = 1.36 \text{ litres of 93.15\% sulphuric acid}$$

$$1.000 \text{ litre} / 1.100 \text{ kg} = ? \text{ litres} / 0.5 \text{ kg}$$

$$? = 0.45 \text{ litres of 85\% formic acid}$$

An alternative to weighing each batch of mortalities is to establish a volume/weight relationship for the ground morts. This relationship will be specific to the grinding method used. The acid addition could then be performed on a volume/volume basis. This is a less precise method of acid addition and the pH of silage created in this manner would require close monitoring.

Immediately after grinding, the acid should be carefully blended into the mort slurry. After this initial blending, a more vigorous stirring is recommended (please refer to the MIXING OF SILAGE section).

The pH of each batch of silage must be tested before it is added to a main storage tank. Fish silage pH should not rise above 2.5 with inorganic acids or above 4.5 with organic acids, or fall below 1.5 with any acid used. If pH is too high, more acid can be added to bring it down to recommended levels. Low pH is more difficult to correct. If the drop in pH is caught soon enough, it is possible to raise pH levels by adding more ground morts. However, this practice will not salvage low pH silage in which the higher concentration of acid has destroyed the natural enzymes.

Sulphuric acid should be added at 3.0 - 3.5% w/w (weight/weight) and then thoroughly mixed. If the pH rises above 2.5 in silage made with inorganic acids, the silage may be susceptible to bacterial spoilage. Any putrid odours that may result defeats one of the main advantages of ensiling and may limit utilization potential. Conversely, initial additions of 4.0% and 5.0% w/w sulphuric acid will result in pH lower than 2 (Appendix D), which retards the reaction and increases production costs.

Formic acid added at 3% w/w maintains the pH at approximately 4. The antimicrobial advantages of formic acid are obtained only if the pH of the silage is maintained *below* 4.5.

ACID SAFETY

Concentrated sulphuric acid is extremely corrosive and appropriate materials and safety equipment must be used. Detailed product safety information (e.g. Material Safety Data Sheet) is attached to acid containers and should be reviewed prior to use. Staff on site should be familiar with first aid procedures in case of accidents with acid.

Formic acid is less corrosive than inorganic acids but requires the same safety equipment. It is recommended that, initially, silage be produced with formic acid until farm staff become experienced with ensilaging procedures and acid handling.

Acid should always be added to ground morts or silage. Never add morts or silage to acid.

All work with acid must be done under well ventilated conditions.

Please refer to the ADDITIONAL EQUIPMENT section for more details.

FRESHNESS COUNTS

Salmon mortalities are generally collected from production cages one to three times per week. The degree of decomposition of these morts will vary with the frequency of collection, size of the fish and ambient water temperatures.

It is imperative that salmon morts be ground or chopped and acidified as soon as possible after retrieval from the sea pens. By adhering to this practice, the existence of sufficient enzymatic activity for digestion is ensured. Using "fresh" morts will also minimize the presence of malodorous compounds, such as putrescine, cadaverine and hydrogen sulphide. Summer mort diving regimes practiced by many farmers (2 - 3 times per week) are sufficient for ensiling purposes as the morts would be deceased no more than four days. If older, decomposing morts are retrieved, it is recommended that they be chopped and added to batches of fresh silage. This will allow the enzymes from recent morts to digest the older carcasses. However, as the older morts will have already started to decompose, odour problems may arise and the overall quality of the silage may be reduced. Depending on the intended end use of the silage, consideration may have to be given to separate storage and disposal of low quality silage.

MACERATION OF MORTS

The entire salmon carcass must be ground or chopped into pieces to release the proteolytic enzymes from the gut regions. Thoroughly macerating the mortalities will result in more surface area being exposed to the acid and enzymes that trigger the start of the autolytic process. The coarseness of the ground morts is a major factor affecting the speed of

liquefaction and the ease with which the silage can be mixed. *The finer the grind and the more thorough the mixing, the more efficient the digestion process will be.*

The most energy efficient mechanism to accomplish this without adding extra water and waste volume is an auger-type meat grinder. Existing auger-type grinders capable of handling large mortalities range in price from \$4,000 to \$13,000 and most require 240 volt single or three phase electric power. Some existing customized auger grinders are gas powered. A secondhand grinder may prove less expensive to purchase, but more difficult to obtain. An additional problem with all but the very large or customized grinders is that the process is labour intensive and will require considerable time to grind large fish. B.C. Packers in Simoon Sound uses a large auger-type grinder (6" diameter) attached to an 11 HP Honda motor. The sieve plate has 1/2" holes and the morts are reduced to a puree. Smaller auger type grinders (3.5" diameter) are also used by Barkley Sea Farms to grind hake for fish feed silage.

A chopper-type macerator manufactured by Whaletown Seafood Equipment has proven quite satisfactory and is available for approximately \$2,800 (Appendix A). In July 1990 field trials, the size of chunks produced by this machine were adequately (98-99%) dissolved in four days using both sulphuric and formic acids (Appendix D). This chopper processed a garbage bucket full of 350 gm to 2 kg morts (approximately 56 kilos) in approximately 5-9 minutes. Choppers of this type are used by Sea Farm Canada and Kanish Aquafarms.

A prototype mort grinder/macerator manufactured by Promac Industries Ltd. of Port Alberni, is being evaluated by Pacific National Group Ltd. at farm sites in Cypress Bay. Test results indicate the grinder effectively reduces salmon carcasses (the largest being 6 kg) to a puree. The unit is designed along the same principles as a kitchen food processor and is powered by the same hydraulic power pack used to operate a pescalator (Archimedes' Screw based fish transporter). It is anticipated this mort grinder will cost \$5,500 without the power pack. A power pack for this unit will cost approximately \$3,000.

All grinders have the capacity to inflict serious injury if operated incorrectly. Therefore, all staff involved in this operation should be properly trained in the equipment's safe operation.

MIXING OF SILAGE

Successful acid ensiling will depend primarily on how thoroughly the acid and fish are mixed. If any pockets or chunks of fish are not penetrated by acid, small colonies of decomposing bacteria will grow and spoil the silage. Producing small batches of silage, in plastic barrels or garbage pails, facilitates thorough mixing during the critical initial stages of the process. This procedure also reduces the risk of contaminating larger storage tanks with an improperly acidified batch of silage. Monitoring small batch containers will ensure adequate liquefaction and proper pH of the batch before it is added to a larger, bulk storage vessel. This procedure is currently used to produce sulphuric acid silage by B.C. Packers in Simoon Sound.

Batch processing may not be necessary when using organic acids. A continuous addition of chopped morts and measured amounts of formic acid to bulk storage tanks is the method successfully used at Sea Farm Canada's Soderman Cove site.

Freshly ground morts form an extremely viscous, or thick, mixture. The addition of acid makes the muscle components of the mixture contract and become rubber-like making stirring difficult. All the salmon farms currently ensiling are using wooden or aluminum paddles to stir this initial mixture. This initial mixture can be made less viscous by adding a small amount of mature liquefied silage (10-12 liters per 50 kilos of freshly ground morts).

Electrically powered mechanical mixers have been used (W. Knight, Trend Feeds, pers comm.), however, appropriate 316 stainless steel mixers are expensive and are best suited to large commercial operations.

Field trials have proven that effective stirring can also be accomplished using a drywall compound mixer (\$15-\$25) attached to a 1/2" or 3/4" electric or gas drill. This combination can stir freshly chopped or ground salmon and is an economical alternative to larger specialized mixers. Drywall mixers must be protected from strong acids with an epoxy or similar resistant coating to prevent corrosion or reaction with their galvanic coatings. Results from MAF/UBC field trials indicate that as a *minimum*, the initial silage mixture should be mixed at least twice daily, once in the morning and again in the evening, for three to four days. This

initial slurry tends to separate into two fractions: a light liquid layer, and heavier salmon chunks and pieces. The mixing should be thorough enough to eliminate any light liquid fraction. During the winter season, a longer period of regular mixing may be required as the liquefaction process proceeds at a slower rate at cooler temperatures. The liquefied mixture can then either be stored in the same container or added to larger bulk storage tanks until disposal.

Unless stored silage is periodically mixed, it will separate into three layers; oil on the top, hydrolysate in the middle and the heavy residue containing bone and skin on the bottom. These separated oils on the surface are more susceptible to oxidation and increased rancidity. Periodic mixing of mature silage is recommended to keep the mixture homogeneous. This mixing will reduce the rate of oil oxidization and help prevent putrefaction of any settled solids. Preliminary recommendations are that stored, liquefied silage be thoroughly mixed at least once a week.

In Norway, small air-cooled outboard motors have been used to stir silage. Their use is *not* recommended in the initial stages of silage formation as the slurry is too dense. Local field trials using a 2.5 HP air-cooled outboard motor clamped to the side of an Xactic tote satisfactorily mixed liquefied silage. However, local information on the motor's durability in this type of application is not available.

Trash-water pumps (W. Knight, Trend Feeds, pers comm.), or magnetically driven plastic pumps with appropriate strainers on intake hoses can also be used to circulate the silage when it is in a highly liquid state. It should be noted, however, that pumps are liable to corrode unless they are constructed of suitable acid resistant materials.

SELECTION OF MATERIALS

All acids are corrosive and farmers should pay particular attention to the material composition of equipment to be used in the ensiling process.

Generally, galvanized surfaces must be avoided since contact with strong acids will cause galvanic corrosion and produce explosive gases (oxygen and hydrogen gas mixtures). Nylon is also susceptible to attack from

strong acids and should be avoided. Ordinary steel or cast iron is not recommended because of probable corrosion and pitting which may result in leakage problems. Acid resistant bladders can be manufactured to line new steel containers, however, fitting such bladders to old steel containers is usually not practical or economical. Although the fats and oils present in silage provide some insulation against corrosion, any inadvertent exposure to concentrated acids will damage susceptible materials.

The silage containers must be made of acid resistant materials. These include polyvinyl chloride, chlorinated polyvinyl chloride, polypropylene, polyethylene, glass-lined steel or noncorrosive 316 AISI stainless steel. Fiberglass is also acceptable if an isophthalic resin (Mallinson 1969) is used in construction. Epoxy resins resist corrosion very well but are more expensive than polyester resins.

The acid storage container should have a dispenser capable of filling a smaller graduated jug or cylinder. Drum or carboy pumps are available and recommended for this purpose. One farm operation which was surveyed utilizes a plastic gas siphon pump to dispense concentrated sulphuric acid.

STORAGE CONTAINERS

There are many suitable tanks and containers available from B.C. suppliers which could be used for storing the prepared silage. The type, size and number of the storage units used will depend on farm location, projected volume of morts, proposed transport method and the length of time between disposals, etc. Silage storage containers presently employed on farms range from plastic, insulated fish totes (Kanish Aquafarms and Barkley Sea Farms) to a pair of 4,500 litre polyethylene water tanks built into a work float (B.C. Packers). Several local companies offer polyethylene and polypropylene tanks in a variety of sizes, including tanks which can be sealed and transported by vehicles or vessels.

An economic alternative are wide-mouth plastic drums (olive and juice barrels) which can be purchased for \$10-\$20 (Appendix A). The containers can be used for batch processing and, if space availability is not a problem, they may be used for long term storage. These plastic

drums are available with a watertight seal and are suitable for transport. This type of container may be especially convenient in areas where pumping silage off the farm into bulk transporters cannot be arranged.

A large membrane-lined, vertically oriented, floating container was used for silage production and storage with varied results by a former fish farming company. Many of the difficulties experienced with this container seem related to processing and equipment shortcomings. This type of system may still prove to be a viable option in the future pending modifications by the manufacturer.

A 2,730 litre (600 gallon) silage storage container is also available in stainless steel or aluminum and can be transported on a flat-bed truck (See Appendix A).

Storage and transport containers with lids and tight seals will prevent spillage, minimize the chance of any possible odours and help reduce the attraction of flies.

It should be noted that although aluminum and most common stainless steels may be adequate for storage of finished silage, they are not recommended for initial batch processing with sulphuric acid. Storage containers fabricated from these metals will corrode when exposed to concentrated acids during initial mixing or when acid condensation forms. Field trials have identified plastic juice barrels or plastic fish totes (both with lids) as the most practical and cost effective containers for batch processing. The ensiling process is accelerated as temperatures increase up to 60°C, above which the proteolytic enzymes are destroyed. Dark coloured containers are recommended as they absorb solar energy and raise silage temperatures.

Improperly processed silage will be subject to bacterial degradation. This will likely result in the production of large volumes of gases. Therefore, frequent venting (i.e. during regular batch mixing) or venting mechanisms may be required if airtight lids are used on batch containers.

Some potential end uses for the silage produced on fish farms will stipulate an allowable maximum size of solids in the silage. In this case, the farm's storage tank(s) would be drained of liquefied silage and any large solids would remain in the tank for digestion with the next batch of silage. If the container is to be emptied by pumping (i.e. vacuum pumped

into a septic tanker truck), a strainer should be placed on the intake hose. These strainers are available in plastic to fit suction hoses with NPT fittings and should have strain holes no larger than the allowable solid size. The storage tanks should have a large access cover to facilitate the insertion of hoses or pumps. In addition, a valved access port at the bottom of the tank would facilitate complete emptying and cleaning or recirculation/mixing of the tank. In liquid state, the silage can be pumped with any acid resistant pump capable of handling small amounts of soft solids.

ODOUR MASKER AND ANTIOXIDANTS

Odour masking compounds are available, but are only required if the silage is destined to become a retail fish fertilizer product. Citronella oil is a compound commonly used to mask odours from fish fertilizer. It has a citrus-like odour and it is thought to deter cats and dogs when the fertilizer is applied in gardens. This material can be supplied on request from Van Waters and Rogers or Argent Laboratories. It is added to fish silage at 0.15% w/w.

The oil in salmon silage oxidizes and becomes rancid if stored for long periods without mixing. An antioxidant commonly used in fish silage destined for animal feed is ethoxyquin. If the silage is to be used in the production of a soil enhancement product, specialized antioxidants are neither required nor recommended.

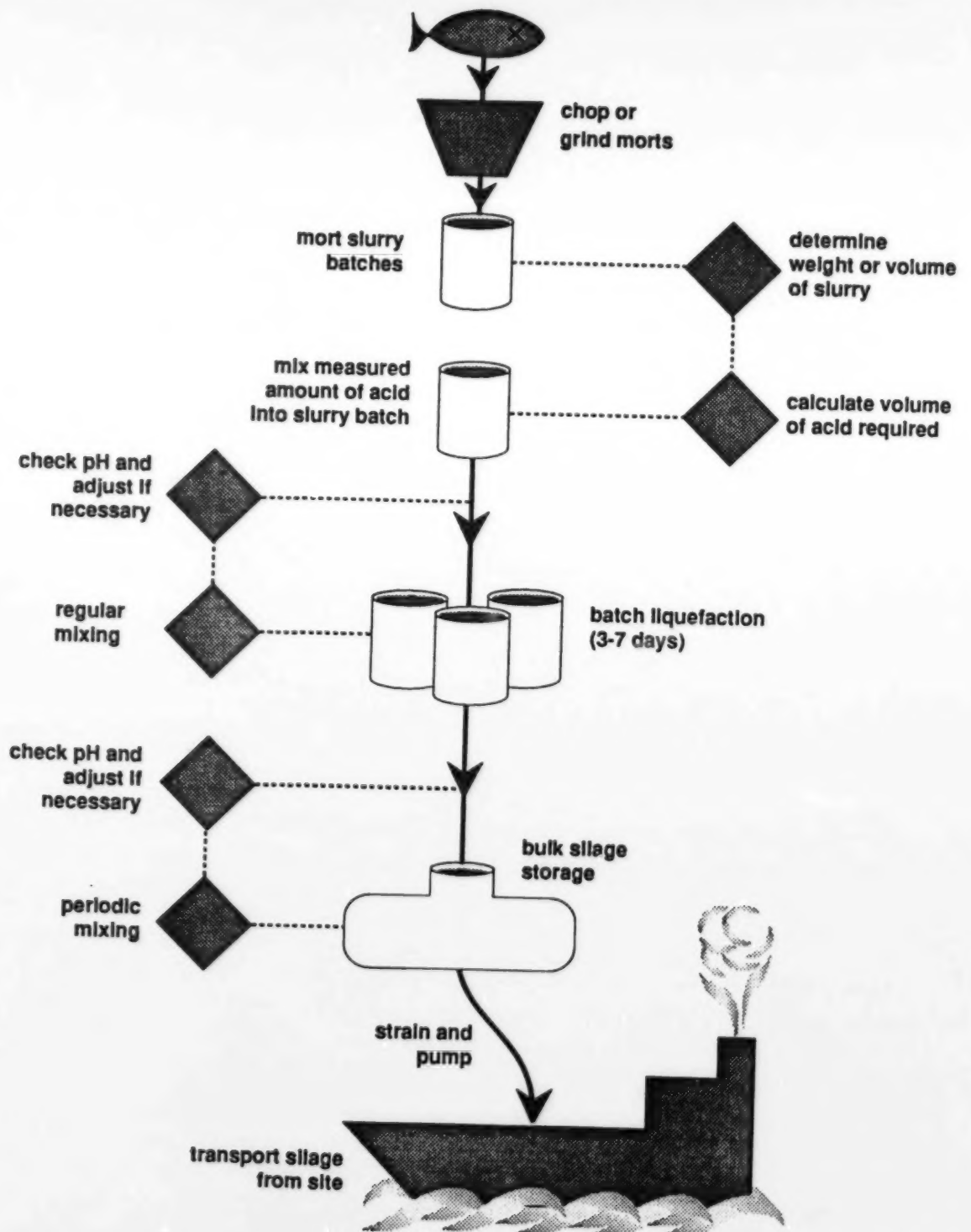
ADDITIONAL EQUIPMENT

Protective equipment for handling acids must be used. Typically, these would include elbow-length natural rubber or neoprene gloves, a neoprene rubber apron or rain gear, rubber boots, face-shield and a carbon air filter mask. There must also be an eye wash station in close proximity to where acid is stored and used.

A method to monitor pH is also required. Either pH strips or pH meters should be purchased and used to ensure that the pH is within optimum ranges.

It is recommended that ensiling machinery and materials be located separate from staff accommodations and grow-out sea pens. If no upland area is available for an ensiling station, a work float would be required for storage tanks, grinders and acids. These work areas should have a nonskid surface.

ENSILING FLOW CHART



RECOMMENDED ENSILING RECIPE & PROCEDURES

Comments:

It is recommended that the ensiling machinery and materials be separated from staff accommodations and grow-out sea pens. In many situations this would mean construction of a raft to contain or support the storage tanks, grinders and acids. Any such work area should have a nonskid surface.

Persons making acid silage should wear full raingear, boots, full face mask, elbow-length rubber gloves and carbon filter breathing mask. An eyewash station *must* be close at hand. The acidification should occur in a well ventilated location.

- Step A)** Chop or grind mortalities *immediately* after retrieval into pieces that are in the order of 2.5 - 3.8 cm (1" - 1.5 ") in diameter. Whole tails and skins are acceptable, as field trials indicate they will eventually dissolve. In addition, morts smaller than 300 grams do not appear to require extensive maceration to ensile quickly. However, it is recommended that *all* morts be passed through a grinder or chopper.
- Step B)** Add 3% weight by weight (w/w) of either sulphuric acid (93.15%), or 3% w/w of formic acid (85%), or 6:1 or 5:1 sulphuric/formic combination at a total 3% w/w. Acid should be added to the batch container *after* the morts are ground. The bulk acid containers must be stored in a secure location.
- Step C)** Ensile the morts in *batches*, in containers that can be sealed until the silage is thoroughly liquefied.
- Step D)** Stir the freshly acidified mixture thoroughly. Mix the batch twice daily. MAF/UBC field trials indicate that it is sufficient to mix once in the morning and once in the evening until the mixture's

low viscosity fraction (acid and surface oils) is resuspended. This procedure is repeated until the mixture liquefies (3 to 7 days, depending on temperature and degree of maceration).

Step E) Check the pH before the batches are added to storage containers. If the pH is too high adjust the pH with more acid if required.

Organic Acid Silage	Maximum allowable pH: 4.5
Inorganic Acid Silage	Maximum allowable pH: 2.5

Step F) If desired, transfer batched silage to large bulk storage containers. Production and storage of the silage must be in acid resistant containers.

Step G) Periodic stirring (once per week) and measurement of the pH in large storage containers is strongly recommended. If required, adjust pH by adding acid. It is important to ensure an antimicrobial environment is maintained.

Step H) The silage by-product must be strained before being shipped to a utilization facility. Any large particles should be retained for further digestion in the continued ensiling process. It should be noted that the current utilization facility at the UBC Research Farm in Oyster River requires that particle size not exceed 1.27 cm (0.5") in diameter. Composting facilities may not have this requirement. Fish fertilizer facilities will likely stipulate that silage must be virtually free of solids.

Step I) To maintain hygiene and reduce odours all equipment in contact with the silage (grinders, batch containers, pumps, etc.) should be washed down after use.

SOME PRACTICAL ENSILING SYSTEM OPTIONS

In selecting the equipment and systems to be employed for ensiling morts on site, fish farmers must take into consideration a number of operational and logistical factors: What volume of morts are expected over the year and what will the likely distribution frequency be? How will the silage be removed from the farm site and to where? Will the silage station be floating or land-based? What would be the optimum amount of on-site storage capacity? Could more than one site use the silage station effectively? What is needed to ensure the safety of staff working the silage station?

The answers to these and similar questions will assist salmon farmers in establishing and operating a mort ensiling station that will be particularly suited to the specific conditions of their site(s).

Over the last few years, several aquaculture and support service companies have been working on the development of mort silage systems and equipment. It has been a process of trial and error for many, but most of the necessary key components have been developed in various regions of the province. Visits to every fish ensiling system on the B.C. coast, scientific and technical literature searches and specific field trials have proven the knowledge and equipment needed to successfully ensile morts is available today in British Columbia.

To provide some examples of the type and scale of ensiling operations farmers may consider, ministry staff have derive materials lists for two typical ensiling systems. It is hoped that these system outlines will prove a useful guide to farmers when designing their own mort silage station.

OPTION A: ENSILING SYSTEM FOR A MEDIUM SIZE SALMON FARM

Primary Assumptions:

- Farm produces approximately 200 tonnes of Chinook salmon annually;
- Mortality rate from smolt to harvest is 36%;

- Site has no significant broodstock population;
- Approximately 60,000 kg of morts generated in each year of steady-state production (Appendix E);
- Morts are recovered every third day from all net cages. An average of 500 kg of morts (approximately 0.5 cubic meters) are recovered each dive day;
- Maceration of the morts will reduce *volume* by 15% (i.e. 0.5 cu.m. of morts will yield 0.425 cu.m. of ground fish);
- Batched silage to be mixed and held in barrels for four days before being added to larger storage containers;
- Silage station to be located on existing work float;
- Silage to be picked up from farm every eight weeks by contracted transport company.

General Equipment & Materials List For Option A System:

Qty	Item Description
1	Mort Chopper (stainless steel) & gas power unit
1	sturdy structure to support chopper assembly over batch barrels
10	plastic barrel (150 litre) with lid
3	500 gal (2,270 litre) polyethylene tank
1	wooden canoe paddle for initial mixing in of acid
1	polypropylene drum pump for acid
1	graduated cylinder/container
1	drywall compound mixer
1	1/2" electric drill
1	extension cord (as required)
1	portable gas generator to power drill
pkg	ColourpHast pH strips
1	emergency eye wash station
2 pr	rubber/neoprene acid gloves
2	face shield
2	carbon filter mask
-	sufficient nonskid surfacing for work float

A silage system incorporating the above items and following the ensiling recipe and procedures recommended on page 18 could be expected to:

- chop 500 kg of salmon morts in 90 minutes or less;
- have a batch storage capacity of 1,500 litres which could accommodate a maximum of 1,760 kg of morts after grinding;
- require 8.165 liters of sulphuric acid per 500 kg morts each processing day. Assuming 122 processing days per year, this farm would use a about 5.4 drums of acid in a full production year;
- have 6,800 litres of bulk storage capacity which could accommodate liquefied silage produced from approximately 7,750 kg of morts.

OPTION B: ENSILING SYSTEM FOR A LARGE SALMON FARM

Primary Assumptions:

- Farm produces approximately 600 tonnes of Chinook salmon annually;
- Mortality rate from smolt to harvest is 36%;
- Site has no significant broodstock population;
- Approximately 180,000 kg of morts generated in each year of steady-state production (Appendix E);
- To ensure morts are no older than four days, mort dives for half the site's sea pens are conducted every second day. An average of 990 kg of morts (approximately 1.0 cubic meter) are recovered each dive day;
- Maceration of the morts will reduce *volume* by 15% (i.e. 1.0 cu.m. of morts will yield 0.85 cu.m. of ground fish);

- Batched silage to be mixed and held in totes for four days before being added to larger storage containers;
- Silage station to be located on leased uplands adjacent to the farm;
- Silage to be picked up from farm every eight weeks by contracted transport company.

General Equipment & Materials List For Option B System:

Qty	Item Description
1	Mort Grinder
1	hydraulic power pack (as per pascalator)
1	sturdy structure to support chopper assembly on top of batch totes
5	plastic insulated tote (approximately 1,000 litres) with lid
6	1,000 gal (4,546 litre) polyethylene tank
2	wooden canoe paddle for initial mixing in of acid
1	polypropylene drum pump for acid
1	graduated cylinder/container
1	drywall compound mixer
1	3/4" electric drill
1	extension cord (as required)
1	portable gas generator to power drill
1	3" trash pump and required hoses, fitting & valves for transferring silage from batch totes to bulk storage tanks
pkg	ColourpHast pH strips
2	emergency eye wash station
2 pr	rubber/neoprene acid gloves
2	face shield
2	carbon filter mask
-	sufficient non-skid surfacing for work area

A silage system incorporating the above items and following the ensiling

recipe and procedures recommended on page 18 could be expected to:

- grind 1,000 kg of salmon morts in about 65 minutes;
- have a batch storage capacity of 5,000 litres which could accommodate a maximum of 5,880 kg of morts;
- require 16.33 litres of sulphuric acid per 1,000 kg morts each processing day. Assuming 183 processing days per year, this farm would use about 16 drums of acid in a full production year;
- have 27,200 litres of bulk storage capacity which could accommodate liquefied silage produced from approximately 31,000 kg of morts.

TRANSPORTATION OF SILAGE

Depending on the biomass being raised on site and the silage capacity planned for, "mort pick-up" no longer has to be every two weeks. Instead, a well-planned operation could operate with regular removal of silage from the farm every 8 - 14 weeks or more. This can represent substantial savings in transportation costs. Of course farms vary in production size, distance from waste utilization facility, local costs for marine and land transport, etc. However, through effective cost benefit analysis, farmers can determine the optimum silage storage capacity for their site(s) so as to realize maximum savings in operational costs through reduced transportation charges.

It must be remembered that silage is about 80% water and transport systems must account for its inherent dynamic nature. Also, silage is denser than water and requires more energy to move. The specific gravities of silages made with 3% w/w formic and sulphuric acid are 1.05 and 1.18, respectively.

As is common when transporting any liquid, both marine and highway transport must be made in leak proof, and preferably airtight, containers that are securely fastened to the carrier. Most transport companies will use an on-board pump system to transfer the silage from farm storage tanks to custom containers. With no smell and little, if any, mess, properly handled silage disposal becomes as routine as the delivery of diesel fuel to a farm.

Acidified fish silage falls into a gray zone when interpreting Provincial transport regulations (Appendix C). The transport vehicle operator is obligated to determine if the cargo falls within the categories specified in the regulations. Since 3% w/w sulphuric acid silage can have a pH of 2.0, it is recommended that the transport decal required for corrosive materials be obtained and displayed when transporting silage by vehicle.

It should be noted that delivery of silage to any utilization plant is facilitated by having a discharge delivery hose and control valve on the transport tank.

THE COST OF ENSILING MORTS

As any fish farmer will appreciate, the cost of producing mort silage will vary somewhat from farm to farm. Some of the factors that must be considered are: inventory size and mortality rate, degree of silage system mechanization, whether equipment is purchased new or used, what suitable materials are already available on site, management and staff efficiency, labour costs, etc.

A series of cost estimates have been derived for system options "A" and "B" (detailed on pages 21 and 23 respectively) so as to provide some insights into the impact mort ensiling will have on a farm's cost of production. The assumptions on which the following estimates are based are detailed in Appendix F.

Initial Capital Requirements For Equipment & Materials

<i>Scenario</i>	<i>Option A</i>	<i>Option B</i>
(I) All items purchased new	\$6,000	\$21,100
(II) Less new purchases due to existing items on site	\$4,800	\$14,500

Using the above estimated expenditures for each system, the following annual operating costs have been calculated:

**Annual Production Costs
For "Option A" Mort Ensiling**

Depreciation: Equipment & Materials	\$ 960	(\$1,200)*
Bulk Acid (Sulfuric)	620	
Labour	3,840	
Annual Cost of Silage Production	\$ 5,420	(\$5,660)*
Quantity Morts Processed (kg)	60,000	
Cost per kg Morts (\$/kg)	\$ 0.090	(\$0.094)*
Farm's Annual Harvest Production (kg)	200,000	
Impact on Cost of Production (\$/kg)	+\$ 0.027	(\$0.028)*

**Annual Production Costs
For "Option B" Mort Ensiling**

Depreciation: Equipment & Materials	\$ 2,900	(\$4,220)*
Bulk Acid (Sulfuric)	1,850	
Labour	5,990	
Annual Cost of Silage Production	\$ 10,740	(\$12,060)*
Quantity Morts Processed (kg)	180,000	
Cost per kg Morts (\$/kg)	\$ 0.060	(\$0.067)*
Farm's Annual Harvest Production (kg)	600,000	
Impact on Cost of Production (\$/kg)	+\$ 0.018	(\$0.020)*

* Scenario (I) - all equipment and materials purchased new

The disposal of unprocessed morts can incur transportation costs that vary from inconsequential (burial in a nearby mort pit) to as much as \$245 per tonne (contract mort pick-up service). Some aquaculture companies are currently delivering mort silage to the UBC Research

Farm for costs ranging from \$95 to \$185 per tonne (Appendix F). As more farms choose to ensile their morts, transportation infrastructures will develop and the cost of shipping silage to utilization facilities should decrease. For the purposes of the following comparison, the higher current transportation costs for both morts and silage were used.

Comparison Of Transportation Costs Unprocessed Morts vs. Mort Silage

	Transport Cost (per kg morts)	Contribution to Farm's Cost of Production (per kg harvested)
Unprocessed morts	\$ 0.245	\$ 0.074
Processed Silage	\$ 0.185	\$ 0.055

In summary, it is estimated the total cost of ensiling salmon mortalities, as outlined in these guidelines, will add between \$0.03 to \$0.08 per kilogram of fish harvested. For companies currently using expensive mort pick-up services, ensiling would prove effective in reducing waste disposal costs.

For those farm companies using mort pits near their sites or some other temporary disposal means, the switch to ensiling will obviously add to their cost of production. However, it must be remembered that:

- mort pits are being phased out as a waste disposal option for aquaculture operations;
- the risk of being fined thousands of dollars for improper disposal of fish wastes is greatly reduced when morts are ensiled;
- a farm that adopts ensiling, or any other processing method to recycle morts into a usable by-product, becomes more environmentally responsible; and,
- managers will find farm staff much more willing to create silage after mort dives than drag buckets of rotten fish up to the pit.

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APPENDIX A

SUGGESTED LIST OF SUPPLIERS

This appendix is not an exhaustive list of all possible suppliers. Individual farmers are advised to select materials appropriate to their own situation and scale of operation. Operators may wish to purchase materials that are able to withstand the more corrosive mineral silages. *Be sure to specify the equipment's or material's intended use to the supplier.*

All prices quoted as of July, 1990.

1.0 ACID SUPPLIERS

Van Waters and Rogers
9800 Van Horne Way
Richmond, B.C.
ph: 273-1441

Harcros Chemical Group
636 Chester
Annacis Island, B.C.
ph: 525-8411

Note: All subsequent prices are as quoted by Van Waters and Rogers, July 1990.

1.1 Sulphuric Acid Conc. (93.15%)

Specific gravity is 1.836

Sold in 40 kg (25 liter) carboys (\$7.00 deposit on each carboy)

Price per kg	Quantity (carboys)
\$1.58	1 - 2
\$0.58	3 - 4
\$0.44	5 - 9
\$0.40	10 - 19
\$0.37	20 - 49
\$0.34	> 50

Bulk acid available in 45 gallon (205 liter) drums (340 kg) for \$115.60 each (plus \$60.00 deposit on drum). This equates to a comparative unit cost of \$0.34 per kg.

To ensile 1,000 kg of morts by adding 3% (w/w) sulphuric acid would cost \$10.20 if the acid is purchased in bulk.

1.2 Formic Acid (85%)

Specific gravity is 1.10

Sold in 25 kg (25 liter) carboys (\$7.00 deposit on each carboy)

Price per kg	Quantity (carboys)
\$4.00	1
\$2.32	2 - 11
\$2.19	12 - 39
\$2.08	> 40

Bulk acid available in 45 gallon (205 liter) drums (226 kg) for \$359.35 each (plus \$60.00 deposit on drum). This equates to a comparative unit cost of \$1.59 per kg.

To ensile 1,000 kg of morts by adding 3% (w/w) formic acid would cost \$47.70 if the acid is purchased in bulk.

1.3 Phosphoric Acid (85%)

Specific gravity 1.425

Sold in 32 kg (25 liter) carboys (\$7.00 deposit on each carboy)

Price per kg	Quantity (carboys)
\$4.00	1 - 4
\$2.32	5 - 24
\$2.19	25 - 59

To ensile 1,000 kg of morts by adding 3% (w/w) phosphoric acid would cost \$63.60 if the acid is purchased in bulk.

1.4 Hydrochloric Acid (31.45%)

Specific gravity is 1.16

Sold in 22 kg (25 liter) carboys (\$7.00 deposit on each carboy)

Price per kg	Quantity (carboys)
\$1.75	1 - 2
\$1.35	3 - 4
\$0.75	5 - 9
\$0.58	10 - 19
\$0.53	20 - 49
\$0.50	> 50

Bulk acid available in 45 gallon (205 liter) drums (240 kg) for \$94.80 each (plus \$60.00 deposit on drum). This equates to a comparative unit cost of \$0.40 per kg.

To ensile 1,000 kg of morts by adding 3% (w/w) hydrochloric acid would cost \$12.00 if the acid is purchased in bulk.

1.5 Propionic Acid (99%)

Specific gravity is 0.966

Available only in bulk 205 liter drums (198 kg) for \$445.50 each (plus \$60.00 deposit on drum). This equates to a comparative unit cost of \$2.25 per kg.

1.6 Costs of Sulphuric/Formic Acid Mix per 1000 kg of Morts (Based on bulk prices - Van Waters and Rogers)

Acid Ratio	Cost
6:1	\$15.58
5:1	\$16.45
2:1	\$22.70
1:1	\$28.95

2.0 ACID PUMP SUPPLIERS

Hank's Dairy Supply Ltd.
4741 Bench Rd.
R.R. 7
Duncan, B.C.
V9L 4W4
ph: 748-1191

Western Industrial Distributors Ltd.
144 West 15th St.
P.O. Box 86846
North Vancouver, B.C.
ph: 980-7821

3.0 pH STRIPS AND METERS

BDH Chemicals
60 E 4th Ave
Vancouver, B.C.
ph: 873-5121
(ColorpHast sticks)

Sealand Sales
316 W. 6th Ave.
Vancouver, B.C.
ph: 875-6599
(pH meter, pH paper)

4.0 PLASTIC BARREL SUPPLIERS :

A. Bossa and Co.
562 Victoria Drive
Vancouver, B.C.
ph: 253-5578
(open mouth Olive Barrels @ \$10 - \$15)

Sun Rype Products Ltd.

Mr. Bob Mayert

ph: 860-7973

(open mouth barrels @ \$20)

Van Isle Products

562 John St.

Victoria, B.C.

ph: 382-7342

(standard holed plastic barrels @ \$20)

Northwest Plastics Ltd.

224-D Cayer St.

Coquitlam, B.C.

ph: 525-8332

(barrels and totes)

Plastic barrels suitable for silage are widely used by local oyster growers. It may be possible to purchase barrels from growers in your area.

5.0 HOSE INTAKE STRAINERS;

Pacific Fire Equipment

1517 Quadra St.

Victoria, B.C.

ph: 386-8321

6.0 LIQUID STORAGE TANK SUPPLIERS

Alpha Fiberglass

10218 Bowerbank

Sidney, B.C.

ph: 656-5121

(fiberglass tanks)

Conchem

19388 Enterprise Way

Surrey, B.C.

ph: 533-0706

(polyethylene tanks)

Manco Septic Solutions
23867 40th Ave, R.R. #12
Langely, B.C.
V3A 7B9
ph: 534-2614
(polyethylene tanks)

Whaletown Seafood Equipment
Cortes Island, B.C.
ph: 935-6445
(aluminum or stainless steel containers)

Danbuoy Ltd.
3473 River Road West
Ladner, B.C.
ph: 946-4544
(Sealo containers)

7.0 SILAGE PUMPS

Flygt Canada
74 Glacier St.
Coquitlam, B.C.
V3K 5Y9
ph: 941-3659

Bancroft Western Sales
1630 McGuire Ave.
North Vancouver, B.C.
ph: 984-4558
(Magnetically driven pump)

8.0 SILAGE MIXERS

Flygt Canada
74 Glacier St.
Coquitlam, B.C.
V3K 5Y9
ph: 941-3659

Various local building supply stores
(Drywall compound mixer @ \$18-25)

9.0 MORT CHOPPERS/MACERATORS

Whaletown Seafood Equipment
Cortes Island, B.C.
ph: 935-6445
(Mort Chopper)

Promac Industries Ltd.
Port Alberni, B.C.
ph: 724-0101
(hydraulic powered grinder/macerator)

Loewen Welding and Manufacturing Ltd.
P.O. Box 66, 33655 Harris Rd.
Matsqui, B.C.
ph: 826-7844
(proposed grinder)

Kasco Food Equipment
2619 Clarke St.
Port Moody, B.C.
ph: 936-0451
(food grinders)

Hobart Canada Inc.
611 Dunedin
Victoria, B.C.
ph: 385-6721
(food grinders)

Hobart Canada Inc.
#2 - 4751 Shell
Richmond, B.C.
ph: 276-2213
(food grinders)

10.0 SAFETY EQUIPMENT

Safety Supply Canada
240 East 10th Ave.
Vancouver, B.C.
ph: 879-5234

Safety Supply Canada
722 Spruce St.
Victoria, B.C.
ph: 382-3186

Fleck Brothers
4084 McConnell Rd.
Burnaby, B.C.
ph: 420-3535

Appendix B : ACID ENSILING OF VARIOUS FISHERY BY-PRODUCTS

A summary of several studies employing various acids to produce stable silages of given pH from fishery by-products

Raw Material	Type and Level of Acid Added (%)	Acid Ratio	pH of Silage	Reference
Herring	Formic (2) ¹	-	4	Jensen and Schmidtsdorf, 1977
Herring	Formic (3)	-	3.8-4.1	Lall and Hines, 1987
Herring	Formic and sulphuric (3)	1:1	3.5-3.8	Lall and Hines, 1987
Herring offal	Formic (1.62)	-	4.4	Olsson, 1942
Dogfish	Formic and Sulphuric (3)	1:1	3.6-3.9	Lall and Hines, 1987
Cod	Formic and Sulphuric (3)	1:1	3.8-4.4	Lall and Hines, 1987
Cod and Saithe	Formic and Propionic (1.5)	1:1	4.5	Strom and Eggum, 1981
Capelin	Formic and Propionic (3)	5:1	4.1	Rungruangsak and Utne, 1981
Capelin	Hydrochloric and Propionic (3)	5:1	4.4	Rungruangsak and Utne
Coal fish	Sulphuric and Propionic (3)	5:1	3.3	Rungruangsak and Utne, 1981
Capelin	Sulphuric and Propionic (3)	1:1	3.8-4.2	Jackson et al., 1984
Pacific Whiting	Sulphuric and Propionic (3)	2:0.75	-	Hardy et al., 1984
Pacific Hake	Phosphoric	-	3.6-3.7	Timmerman, 1978
Pacific Hake	Formic and Sulphuric (3)	1:1	-	Richards, 1990
Pacific Salmon	Sulphuric (3)	-	2.5-3.0	Fellbullen, 1990
Pacific Salmon	Sulphuric (3)	-	2.5	Ekkert and Carswell, 1990
Pacific Salmon	Formic (3)	-	4.0	Ekkert and Carswell, 1990

¹ Values in parentheses indicate the level of acid added w/w.

APPENDIX C

Provincial Regulation for Transport of Dangerous Goods Part 3.23(2)(b)(ii)

Criteria Class-8 Corrosives

3.25 (1) Not fully specified products or substances that

- (a) have been known to cause visible necrosis of human skin tissue,
- (b) cause visible necrosis of the skin tissue of an albino rabbit at the contact site within a period of four hours or less when administered by continuous contact with the intact bare skin of the rabbit.
- (c) corrode SAE 1020 steel or 7075-T6 non-clad aluminum surfaces at a rate exceeding 6.25 mm per year at a test temperature of 55°C using the metal corrosion test method set out in Part VI of Schedule VI, or
- (d) are wastes that have a pH factor less than 2.0 or greater than 12.5

shall be included in class 8 referred to in the schedule to the Act.

APPENDIX D

MAF/UBC SALMON SILAGE FIELD TRIALS

Methods:

Starting on July 12, 1990, field trials were conducted by B. Carswell, Aquaculture and Commercial Fisheries Branch, Ministry of Agriculture and Fisheries, and J. Ekkert, University of British Columbia. In these trials, triplicate containers of 4.000 kg of macerated salmon morts were mixed with various concentrations and mixtures of acid.

The three to four day old morts were ground using the Whaletown chopper and mixed with 93.15 % Sulphuric or 85% Formic acid or specific ratio mixtures of both acids.

Silage replicates (three) were placed in sealed white buckets which were stored outdoors at the UBC Research Farm at Oyster River for the duration of the trials.

The weight of undissolved residue was measured as the weight of residue retained on a 1.27 cm. (1/2") galvanized screen.

The pH of these silages was measured with both a portable Corning PH 106 meter and ColorpHast indicator sticks.

Results:

The following two tables and three graphs summarize the results of these field trials:

Table 1. Weight of Undissolved Salmon Silage with Various Acid Mixtures

(Total Acid Addition of 3% By Weight)

Day	Acid Ratio (Sulphuric:Formic)	Undissolved Average Weight (kg)	Solids Retained % of Initial Weight of Morts Ensiled	Duncan Grouping*
4	6:1	0.30	7.5	A
4	5:1	0.25	6.3	A
4	3:1	0.36	9.0	A
4	1:0	0.46	11.5	A

* Duncan grouping of statistical means. Means with different letters indicate significant differences at alpha = 95%. Groupings with the same letter are not significantly different (alpha = 0.05).

Table 2. Weight of Undissolved Salmon Silage with Various Acid Amounts.

Day	Acid Concentration (w/w)	Undissolved Average Weight (kg)	Solids Retained % of Initial Weight of Morts Ensiled	Duncan Grouping*
2	3% Formic	0.44	11	A
2	3% Sulphuric	0.40	10	A B
2	4% Sulphuric	0.70	17.5	B
2	5% Sulphuric	1.09	27.3	B
4	3% Formic	0.15	3.8	A
4	3% Sulphuric	0.31	7.8	B
4	4% Sulphuric	0.65	16.3	C
4	5% Sulphuric	0.73	18.3	C
7	3% Formic	0.06	1.5	A
7	3% Sulphuric	0.11	2.7	A B
7	4% Sulphuric	0.25	6.2	B
7	5% Sulphuric	0.52	13.0	C

* Duncan grouping of statistical means. Means with different letters indicate significant differences at $\alpha = 95\%$. Groupings with the same letter are not significantly different ($\alpha = 0.05$).

Figure 1. pH Changes in Salmon Silage

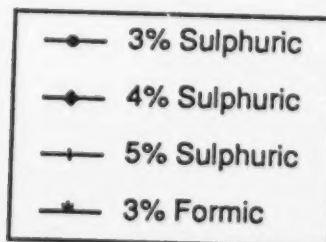
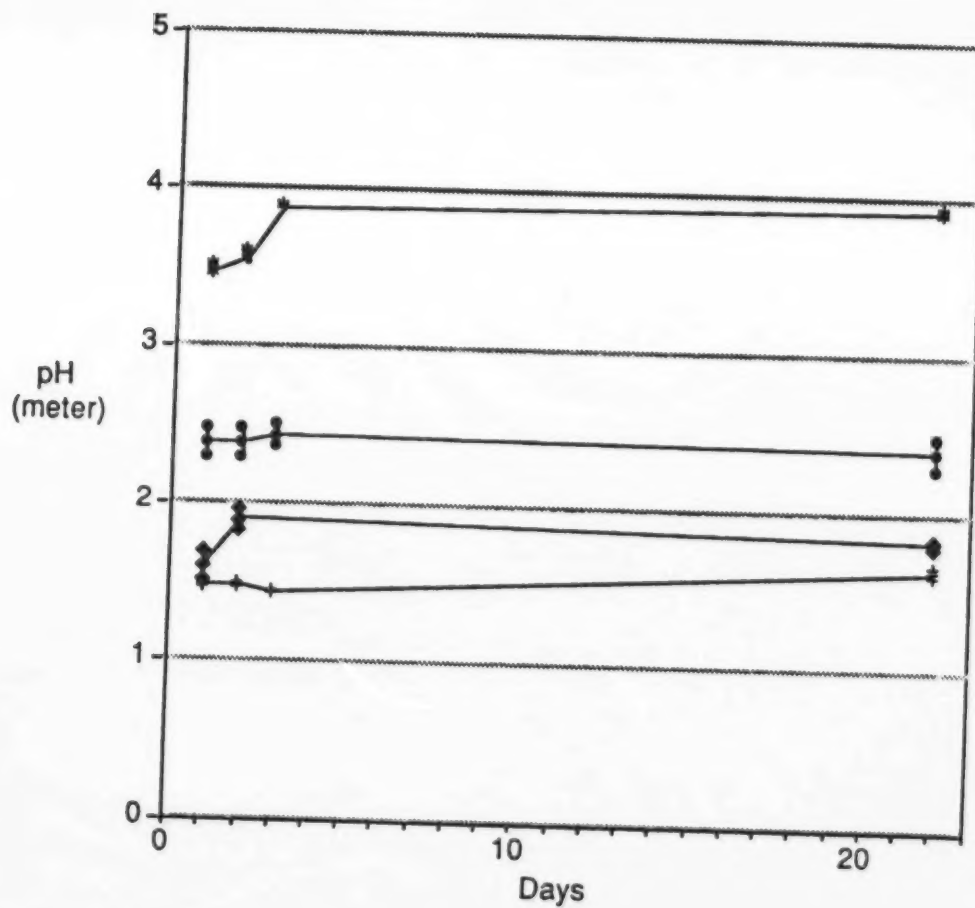


Figure 2. pH Changes in Salmon Silage

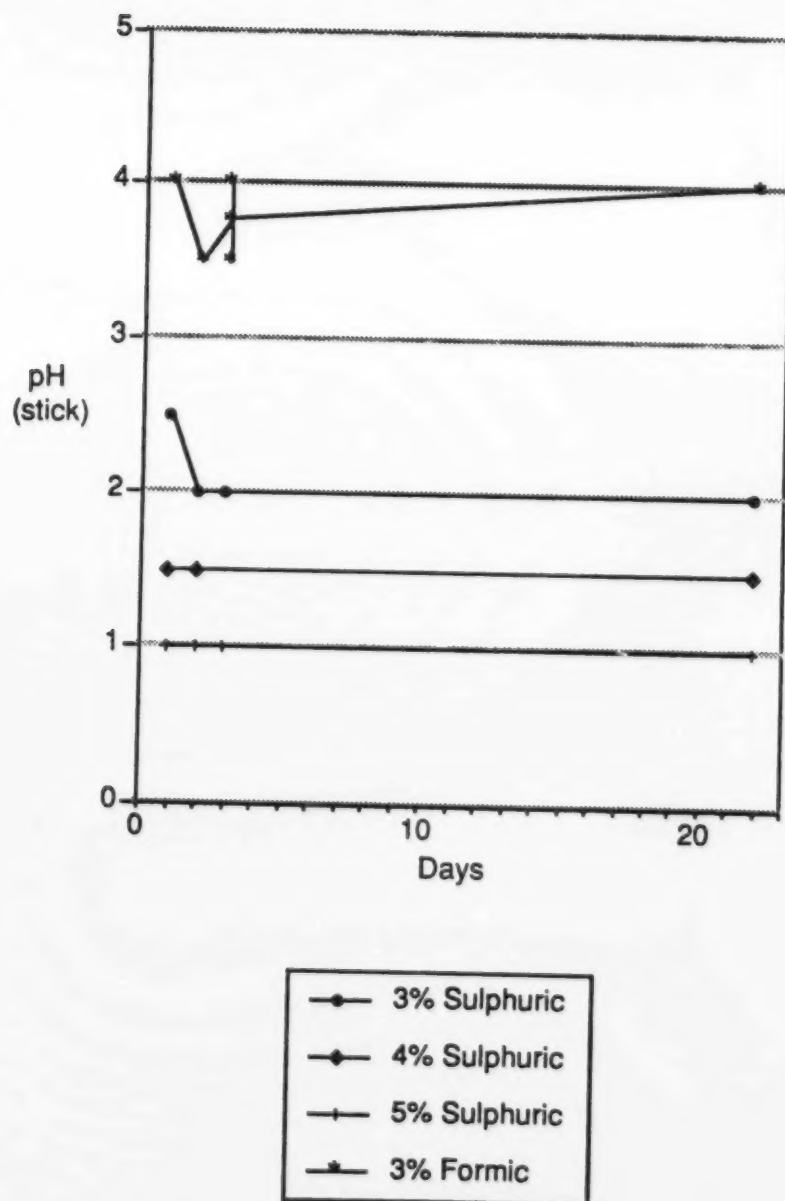
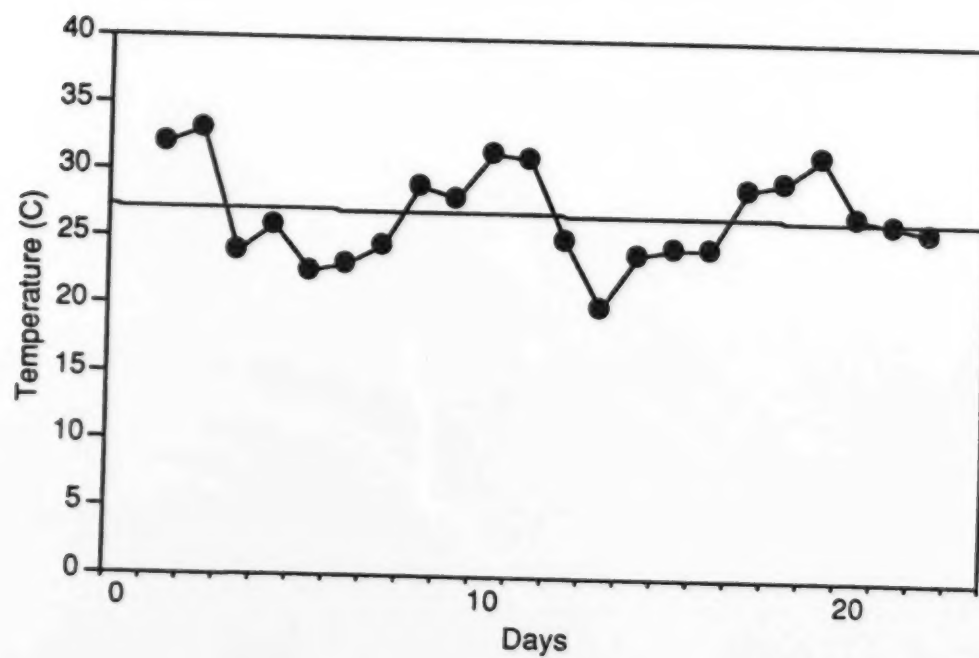


Figure 3. Ambient Daily Maximum Temperature During Trials



APPENDIX E

ESTIMATED MORTALITY PRODUCTION

**Table 1. ESTIMATED MORT PRODUCTION: 200 TONNE
CHINOOK FARM**

	1st Year Class		2nd Year Class		Morts
	Alive	Dead	Alive	Dead	(tonnes/yr)
Start of Month 1					
No. of Smolts	100,000	0	-	-	
Wt. of Smolts (t)	0.8	0	-	-	0
End of Month 12					
No. of Fish	80,000	20,000	100,000	0	
Wt. of Fish (t)	140	20	0.8	0	20
End of Month 24					
No. of Fish	64,000	16,000	80,000	20,000	
Wt. of Fish (t)	200*	40	140	20	60

**Table 2. ESTIMATED MORT PRODUCTION: 600 TONNE
CHINOOK FARM**

	1st Year Class		2nd Year Class		Morts
	Alive	Dead	Alive	Dead	(tonnes/yr)
Start of Month 1					
No. of Smolts	300,000	0	-	-	
Wt. of Smolts (t)	2.4	0	-	-	0
End of Month 12					
No. of Fish	240,000	60,000	300,000	0	
Wt. of Fish (t)	420	60	2.4	0	60
End of Month 24					
No. of Fish	192,000	48,000	240,000	60,000	
Wt. of Fish (t)	600*	120	420	60	180

* Weight of harvested fish

APPENDIX F

ASSUMPTIONS AND CALCULATIONS USED TO ESTIMATE THE COST OF ENSILING

- Cost estimates for ensiling are based on system options "A" and "B", their primary assumptions and the operating procedures described in this document;
- Price quotations used to determine new equipment and materials costs obtained during September, 1990, from companies listed in Appendix A;
- For each system option, two scenarios are used:
 - I) all equipment and materials required are purchased new from B.C. suppliers. All prices are F.O.B. Vancouver and do not include provincial sales tax or G.S.T.;
 - II) certain items required for ensiling are already available on the farm and are removed from the costs incurred in Scenario (I). These items are:

Option A	Option B
1/2" electric drill	hydraulic power pack
portable generator	insulated totes (3)
extension cord	3" trash pump, etc.
wooden paddle	1/2" electric drill
graduated cylinder	portable generator
	extension cord
	wooden paddle
	graduated cylinder
- A conservative 20% straight line depreciation rate is used for all new equipment and materials (i.e. five year life);
- 3% w/w of 93.15% concentrated sulfuric acid is used to ensile. Acid bought in bulk barrels;
- Silage transport costs calculated from information provided by Sea Farm Canada Inc. (Soderman Cove to Oyster River) and B.C. Packers Ltd. (Simoon Sound to Oyster River);

- Specific gravity of 3% sulfuric acid salmon silage is 1.18. Thus, 1,000 gallons silage (4,546 liters) weighs 5,346 kg. Therefore 1,000 gallons of silage is the product of 5,186 kg of morts ($5,346 - 3\% = 5,186$);
- Two field staff take 8 man-hours (option A) and 4.16 man-hours (option B) to ensile 1,000 kg morts. Wages are \$8/hr. The annual cost of labour for each system option is estimated to be:

Option (A): $\$8/\text{hr} \times 8 \text{ hr/tonne} \times 60 \text{ tonnes/yr} = \$3,840/\text{yr}$

Option (B): $\$8/\text{hr} \times 4.16 \text{ hr/tonne} \times 180 \text{ tonnes/yr} = \$5,990/\text{yr}$